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A Real-Time Peak Extraction Algorithm for Dynamic Displacement Measurement Based on Spectral Confocal Microscopy

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A Real-Time Peak Extraction Algorithm for Dynamic Displacement Measurement Based on Spectral Confocal Microscopy

Lijia Liu, Hua Ma, Zhendong Shi, Jinxi Bai and lin Zhang [*]

Laser Fusion Research Center of China Academy of Engineering, No.64, Mianshan Road, Mianyang, Sichuan Province, 621900, China

[*]E-mail: 1520578645@qq.com

Abstract. Spectral confocal is widely used in various fields such as topography detection, roughness measurement, thickness measurement, for its advantages ability in displacement measurement. Developed from confocal microscopy, the spectral confocal microscopy greatly improves the efficiency of displacement measurement because there is no need for longitudinal scanning, In other words, we need to obtain the wavelength information corresponding to the peak point of the spectral signal, which is called peak abscissa but not the peak value. Therefore, Accurate and efficient peak abscissa calculation algorithm occupies an important position in displacement monitoring based on spectral confocal. However, the existing methods are too complex to apply to real-time dynamic online detection, for they usually focus on determining the peak value by means of curve fitting and peak extraction. In this paper, we proposed an efficient and accurate peak abscissa calculation method by shifting, difference, linear fitting, zero point and peak abscissa calculation (SDLZ). Compared with the Gaussian fitting method, the results demonstrate that the SDLZ can greatly improve efficiency, can be applied to field programmable gate array microcontrollers, with high measurement accuracy, providing key solutions for equipment needs.

Keywords. Spectral confocal, displacement measurement, spectral signal, peak abscissa calculation.

1. Introduction

the technology of displacement measurement based on spectral confocal has been carried out widely in many areas such as micro-nano intelligent manufacture, biomedical and biological research, three-dimensional profile measurement and thickness measurement, for its excellent capability in axial discrimination and the characteristic of high efficiency due to non-essential longitudinal scanning. it can be applied to real-time dynamic measurement. With the development of high-end manufacturing, it creates great requirements of the high accuracy and precision measurement technology. In spectral confocal measurement system, different spectral components of a broadband light source to be focused to different heights of the sample surface. Among these spectral components, only the one that focused on the sample surface precisely will be focused on the detector with little power loss and the other wavelengths are stopped by the small aperture cause much power loss. So the wavelength with high intensity is corresponding to the displacement of sample surface. The value of the displacement can be definite by the experiments with laser interferometer. Therefore, the efficiency and precision performance of the peak extraction algorithm occupies an important position in displacement monitoring based on spectral confocal. The existing algorithms are more and more accurate with high complexity such as wavelet fitting, Gaussian fitting and parabolic fitting. They are so complex with poor computational efficiency that is not suitable for rapid measurement application. The algorithm should focus on the wavelength of the spectral signal but not the peak intensity.

In this paper, we proposed an efficient and accurate peak abscissa calculation algorithm by shifting, difference, linear fitting, zero point and peak abscissa calculation (SDLZ). Compared with the Gaussian fitting method, the simulator and experiment results demonstrate that the SDLZ can greatly improve efficiency, can be applied to field programmable gate array microcontrollers, with high measurement accuracy, providing key solutions for equipment needs.

2. Method

The shifting, difference, linear fitting, zero point and peak abscissa calculation (SDLZ) algorithm is described as following:

A raw continue spectral signal with single peak is simulated given as Y, which obeys Gaussian distribution, and the distribution function is Y=50*exp(-(x-5).^2./2);where x = [0:10];

The raw sampling spectral signal with equal intervals which is defined as Y1, Y1=50*exp(-(x-5).^2./2); where x =[0:0.1:10], is shown in figure 1;

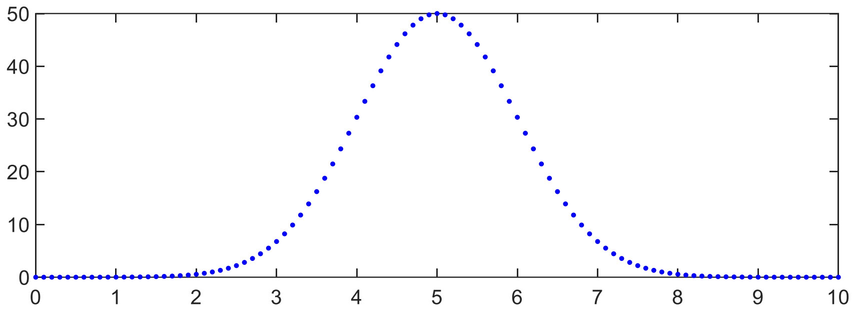

Figure 1. The raw sampling spectral signal.

The shifting signal from the raw sampling spectral signal for a shift of 30 samplings is defined as Y2=50*exp(-(x-8).^2./2);where x = [0:0.1:10], is shown in figure 2;

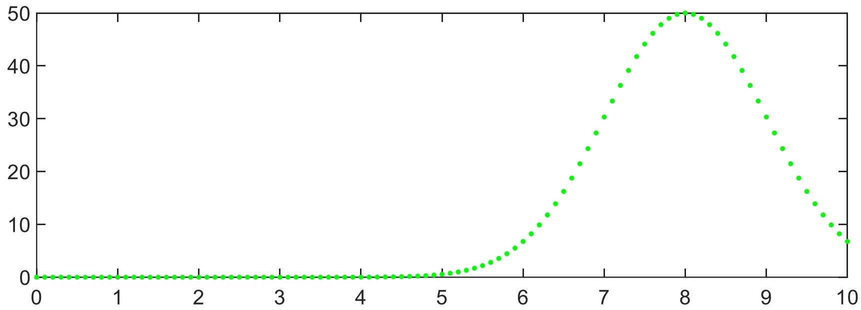

Figure 2. The shifting signal from the raw sampling spectral signal.

The difference signal from the shifting signal is defined as Y3, Y3=Y2-Y; where x = [0:0.1:10], is shown in figure 3;

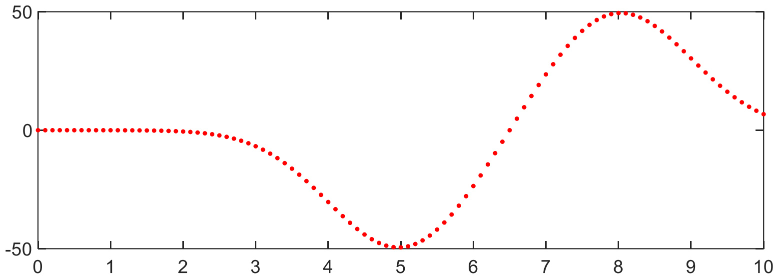

Figure 3. The difference signal from the shifting signal.

The linear fitting signal from the shifting signal is defined as Y4, Y4=cf.A*xi+cf.B; where [cf,gof]=fit(x(30:101),Y3(30:101), type); type=fittype('A*x+B'); xi=[3:0.1:10], is shown in figure 4;

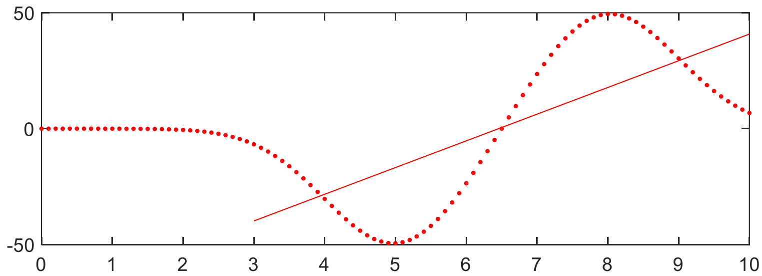

Figure 4. The linear fitting signal from the shifting signal.

The zero point of the linear fitting signal can be calculated by –B/A;
The peak abscissa Xp can be calculated by Xp= –B/A-shift/2, is shown in figure 5;

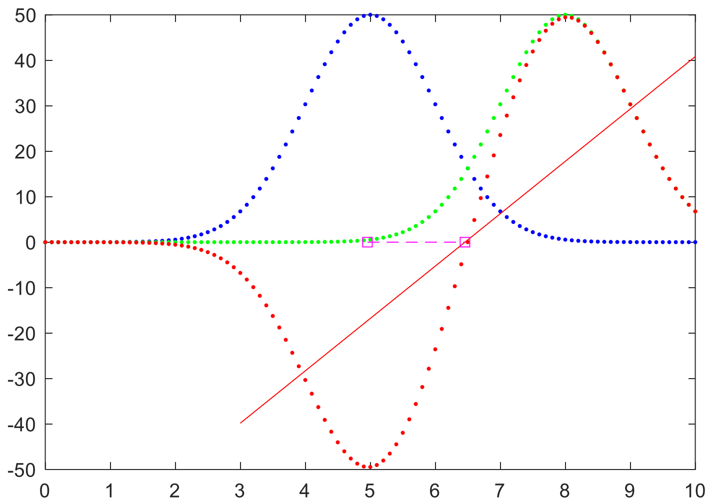

Figure 5. The peak abscissa extraction result.

3. Results and Discussion

The computational efficiency is an important measure when choosing the appropriate peak extraction algorithm, since there is a huge amount of spectral data that need be processed in high-frequency measurement. The gauss fitting (GA) algorithm and the proposed SDLZ are compared implemented in MATLAB R2014a with a CPU of intel core i5-3210M 2.5 GHZ and a RAM of 8GB. When the number of spectral sampling signal is small, the computational efficiencies of these two algorithms keep almost equal. As is shown in table 1, with the number (N) increases, the efficiency of gauss fitting drops significantly while the SDLZ remains efficient.

Table 1. Compare of the computational efficiency.

number	N=10		N=100		N=1000	
algorithm	GA	SDLZ	GA	SDLZ	GA	SDLZ
mean time	50ms	1ms	845ms	12ms	10050ms	156ms

The peak abscissa calculation performance of the SDLZ is demonstrated in experiments. The spectral confocal profile measurement system, which includes the broadband light source (MWWHF2, Thorlabs, USA), the commercial confocal sensor (IFD2451, Micro-Epsilon, German) and the spectrometer (Ocean optic HR2000, USA) is shown in figure 6. The height extraction standard deviations are obtained to represent the peak extraction algorithm performance. The RMS values of height extraction standard deviations are 0.065 μm and 0.059 μm for the SDLZ and GF respectively. From the RMS perspective of height extraction standard deviations, the CFDA can have a comparable peak extraction performance on height extraction standard deviations compared to GF.

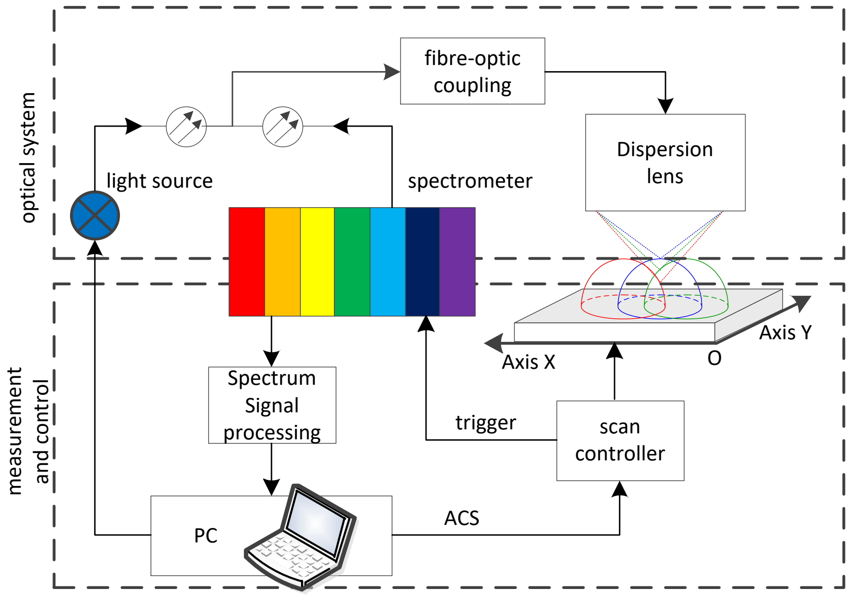

Figure 6. Schematic of experiment system.

4. Conclusion

In this paper, we proposed an efficient and accurate peak abscissa calculation algorithm, including shifting, difference, linear fitting, zero point and peak wavelength extraction (SDLZ). Among the step of the algorithm, there is no complex and poor computational efficiency process. Compared with the Gaussian fitting method, the simulator and experiment results demonstrate that the SDLZ can greatly improve efficiency, can be applied to field programmable gate array microcontrollers, with high measurement accuracy, providing key solutions for equipment needs. It can greatly improve the efficiency of profile, roughness measurement and thickness measurement,

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